

Original Research Article

The Effectiveness of ICL Implantation in Treating Moderate to High Myopia: Analyzing Changes in Anterior Chamber Parameters

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ABSTRACT

Background: This study aims to assess the efficacy and safety of implantable collamer lens (ICL) implantation in correcting moderate to high myopia, with a particular focus on its impact on anterior segment parameters, including anterior chamber depth (ACD), intraocular pressure (IOP), and endothelial cell density.

Material and methods: A prospective, interventional observational study was conducted at a tertiary eye care center from August 2023 to May 2024. Twenty-six patients (44 eyes), aged 18 to 35 years, underwent ICL implantation. Preoperative and one-month postoperative measurements included uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), spherical equivalent (SE), IOP, ACD, central corneal thickness (CCT), and endothelial cell counts. Data were analyzed using paired t-tests and ANOVA with IBM SPSS version 25.

Results: The mean preoperative SE improved from -11.49 ± 4.78 D to -0.87 ± 0.40 D postoperatively ($p < 0.001$). UDVA improved significantly from 0.11 ± 0.035 to 0.87 ± 0.23 ($p < 0.001$), and CDVA improved from 0.85 ± 0.23 to 1.0 ± 0.18 ($p < 0.001$). No statistically significant change in IOP was observed ($p = 0.2$). ACD decreased significantly from 3.32 ± 0.24 mm to 2.59 ± 0.28 mm ($p < 0.0001$). Endothelial cell count showed a slight but non-significant decrease ($p > 0.05$).

Conclusion: ICL implantation is a safe and effective option for correcting moderate to high myopia, with significant improvements in visual acuity and acceptable changes in anterior chamber parameters. Ongoing monitoring of anterior segment structures is recommended for long-term safety evaluation.

Keywords: ICL implantation, High Myopia, Anterior chamber depth, Endothelial Cell Density, Refractive Surgery, Visual Acuity

INTRODUCTION

Myopia, particularly in its moderate to high forms, has become a significant global public health concern. The increasing prevalence of myopia—especially among young adults—has raised the demand for safe and effective surgical interventions that can provide stable

visual rehabilitation and minimize long-term ocular complications. Traditional methods such as spectacles and contact lenses provide optical correction but often fail to meet the expectations of active individuals seeking permanent solutions. Refractive surgeries, including laser-assisted in situ keratomileusis (LASIK) and photorefractive keratectomy (PRK), are

not suitable for all patients, particularly those with thin corneas or extreme refractive errors¹.

Implantable Collamer Lenses (ICLs) have emerged as a viable alternative to corneal refractive surgeries for patients with moderate to high myopia. Unlike LASIK, ICL implantation preserves corneal architecture and is both reversible and adjustable, making it particularly suitable for individuals with contraindications for corneal-based procedures^{2,3}. The Visian ICL, a posterior chamber phakic intraocular lens, is implanted between the iris and the natural crystalline lens and is designed to correct high degrees of myopia while maintaining the eye's accommodative ability⁴.

Despite its proven visual benefits, ICL implantation is associated with anatomical changes within the anterior segment of the eye. Previous studies have reported significant alterations in anterior chamber depth (ACD), anterior chamber angle (ACA), and intraocular pressure (IOP) following ICL implantation^{5,6}. In particular, the narrowing of ACD postoperatively raises concerns about potential complications, such as angle-closure glaucoma or elevated IOP⁷. Furthermore, endothelial cell loss, a known risk factor for corneal decompensation, requires careful monitoring to ensure long-term ocular safety⁸.

The Sirius system—a Scheimpflug imaging-based topographer—alongside non-contact tonometry, has been widely used for precise measurement of anterior segment parameters such as ACD, central corneal thickness (CCT), and white-to-white (WTW) diameter, providing vital data for preoperative screening and postoperative assessment⁹. Adequate central vaulting between the ICL and the natural lens is critical for long-term safety. Insufficient vault may increase the risk of anterior subcapsular cataract formation, whereas excessive vault may predispose patients to pigment dispersion or elevated IOP¹⁰.

Although several studies have evaluated visual outcomes after ICL implantation, fewer have comprehensively analyzed the early postoperative changes in anterior chamber anatomy using advanced imaging modalities. Additionally, there is limited

evidence from the Indian subcontinent, particularly involving young adult populations with high myopia. Therefore, this study aims to evaluate the short-term anatomical and functional outcomes following ICL implantation in patients with moderate to high myopia, with a specific focus on changes in ACD, IOP, and endothelial cell count. The findings will contribute to a better understanding of the safety profile of ICL procedures and guide clinicians in optimizing patient selection and postoperative care.

MATERIAL AND METHODS

Study Design and Setting

This prospective, interventional, observational study was conducted at a tertiary eye care center in Surat, India, from August 2023 to May 2024. Ethical clearance was obtained from the Institutional Ethics Committee (Approval ID: IEC/OPTOM/2023/ICL-017). All procedures adhered to the principles outlined in the Declaration of Helsinki (2000 revision), and written informed consent was obtained from all participants prior to inclusion in the study.

Participants

The study included 26 patients, accounting for 44 eyes, with ages ranging from 18 to 35 years. All patients were diagnosed with moderate to high myopia and were selected through consecutive sampling. Eligibility criteria included a spherical equivalent refractive error between -2.00 diopters (D) and -20.00 D and a confirmed stable refraction of ± 0.5 D for at least one year prior to surgery. The minimum anterior chamber depth required for inclusion was 3.0 mm, measured from the corneal endothelium to the anterior capsule of the crystalline lens. Patients with a history of ocular trauma, previous intraocular surgeries, retinal pathology, keratoconus, pellucid marginal degeneration, cataracts, glaucoma, or uveitis were excluded. Additionally, patients with systemic autoimmune diseases, dry eye syndrome, or those who were pregnant or lactating were also excluded from the study.

Preoperative Assessment

All participants underwent a detailed ophthalmological evaluation prior to ICL implantation. These included measurements of uncorrected distance visual acuity (UDVA) and best-corrected distance visual acuity (CDVA) using the Snellen chart in decimal notation. Refractive error was assessed using both objective and subjective refraction techniques. Intraocular pressure (IOP) was recorded using a non-contact tonometer (Topcon NCT), and anterior segment evaluation was performed through slit-lamp biomicroscopy. Fundus examination was done using indirect ophthalmoscopy to rule out posterior segment pathology. Corneal topography and tomography were carried out using the Sirius system, while endothelial cell density was measured through specular microscopy. Additional biometric parameters including axial length, central anterior chamber depth (ACD), and white-to-white (WTW) distance were measured using the Lenstar LS 900. Central corneal thickness (CCT) was determined using ultrasonic pachymetry. All preoperative assessments were conducted by experienced optometrists using standardized procedures.

ICL Sizing and Selection

ICL sizing and model selection were based on white-to-white and ACD values in accordance with the manufacturer's nomogram (STAAR Surgical, USA). All patients received the fourth-generation Visian ICL V4 lenses, including spherical and toric variants as per individual refractive needs.

Surgical Procedure

A single experienced surgeon performed all procedures under topical anesthesia in a sterile surgical environment. Mydriasis was achieved using 1% tropicamide administered 30 minutes before surgery. A 3.0 mm clear corneal incision was made temporally. After filling the anterior chamber with sodium hyaluronate, the ICL was injected using a sterile cartridge and positioned between the iris and the natural lens. The viscoelastic agent was thoroughly irrigated, and the incision was hydrated to ensure watertight closure. Patients were prescribed postoperative medications including a combination of

moxifloxacin and prednisolone acetate eye drops (four times daily for 4 weeks) and lubricating drops for one month.

Postoperative Follow-up

Postoperative evaluations were conducted on day 1, day 7, and at 1 month following the surgery. Only the one-month postoperative data were included for statistical analysis. During follow-up, UDVA, CDVA, manifest refraction, and IOP were reassessed. Anterior segment imaging was repeated using the Sirius device to measure postoperative ACD and CCT. Endothelial cell count was measured again using specular microscopy. Vault height was assessed via slit-lamp examination and confirmed with anterior segment optical coherence tomography when needed.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). Quantitative variables were expressed as mean \pm standard deviation (SD). A paired two-tailed Student's t-test was used to evaluate changes between preoperative and postoperative measurements. One-way ANOVA was employed when comparing more than two sets of data. A p-value < 0.05 was considered statistically significant.

RESULTS

Demographics and Baseline Characteristics

A total of 26 patients (44 eyes) were included in the final analysis. Of these, 15 were female (57.7%) and 11 were male (42.3%), with a mean age of 24.56 ± 4.98 years (range: 18–35 years). Among the implanted lenses, 20 eyes received spherical ICLs and 24 eyes received toric ICLs. Table 1 summarizes the demographic and surgical characteristics of the study population.

Table-1: Demographic and Clinical Characteristics of Participants

| Characteristic | Value |
|-------------------------------|------------------|
| Total number of patients | 26 |
| Total number of eyes | 44 |
| Gender (Female / Male) | 15 / 11 |
| Age (mean \pm SD, in years) | 24.56 \pm 4.98 |
| Spherical ICL / Toric ICL | 20 / 24 |

Refractive Outcomes

The mean preoperative spherical equivalent (SE) was -11.49 ± 4.78 D. At one month postoperatively, the mean SE was significantly reduced to -0.87 ± 0.40 D ($p < 0.001$), indicating a substantial improvement in refractive status following ICL implantation. This change is reflected in the comparative data presented in **Table 2**.

Visual Acuity Outcomes

Uncorrected distance visual acuity (UDVA) improved markedly from a preoperative mean of 0.11 ± 0.035 (Snellen decimal) to 0.87 ± 0.23 at one month postoperatively ($p < 0.001$). Similarly, best-corrected distance visual acuity (CDVA) improved from 0.85 ± 0.23 to 1.0 ± 0.18 ($p < 0.001$), confirming enhanced visual performance in both uncorrected and corrected states. These improvements are illustrated in **Figure 1** and tabulated in **Table 2**.

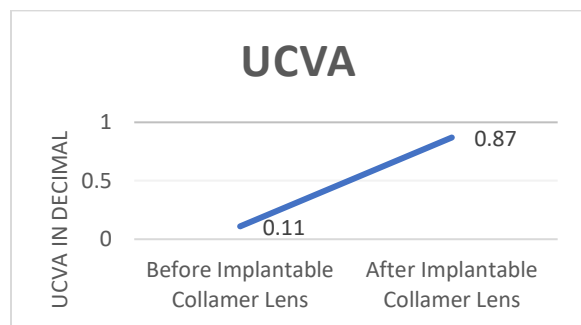


Figure-1: Uncorrected visual acuity before and one month after ICL implantation.

Table-2: Summary of Preoperative and Postoperative Ocular Parameters

| Parameter | Preoperative (Mean \pm SD) | Postoperative (Mean \pm SD) | P-value |
|--|------------------------------|-------------------------------|-----------|
| Spherical Equivalent (D) | -11.49 ± 4.78 | -0.87 ± 0.40 | < 0.001 |
| UDVA (decimal) | 0.11 ± 0.035 | 0.87 ± 0.23 | < 0.001 |
| CDVA (decimal) | 0.85 ± 0.23 | 1.0 ± 0.18 | < 0.001 |
| Intraocular Pressure (mmHg) | 17.55 ± 2.04 | 18.07 ± 2.48 | 0.20 |
| Anterior Chamber Depth (mm) | 3.32 ± 0.24 | 2.59 ± 0.28 | < 0.001 |
| Central Corneal Thickness (μ m) | 506.93 ± 45.42 | 509.43 ± 22.49 | > 0.05 |
| Endothelial Cell Count (cells/ m^2) | 2800 ± 20.54 | 2705 ± 21.78 | > 0.05 |

Intraocular Pressure

The mean intraocular pressure (IOP) prior to surgery was 17.55 ± 2.04 mmHg, which increased slightly to 18.07 ± 2.48 mmHg postoperatively. However, the change was not statistically significant ($p = 0.20$), suggesting that ICL implantation did not induce a clinically meaningful elevation in IOP in the short

term. These findings are shown in **Figure 2** and detailed in **Table 2**.

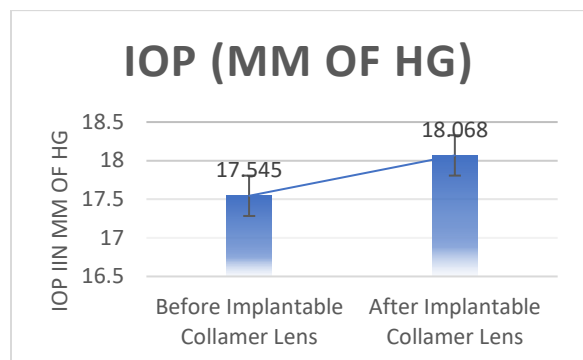


Figure-2: Intraocular pressure before and one month after ICL implantation.

Anterior Chamber Depth

A significant reduction in anterior chamber depth (ACD) was observed postoperatively. The mean ACD decreased from 3.32 ± 0.24 mm to 2.59 ± 0.28 mm ($p < 0.0001$). Despite the anatomical narrowing, no clinical signs of angle closure or iridocorneal synechiae were noted during follow-up. ACD changes are presented in **Figure 3** and summarized in **Table 2**.

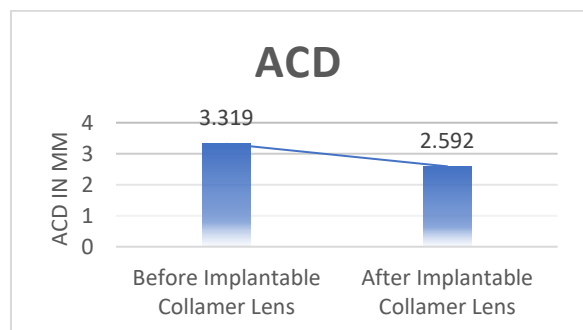


Figure-3: Anterior chamber depth before and one month after ICL implantation.

Central Corneal Thickness

Central corneal thickness (CCT) showed a minor, non-significant increase from 506.93 ± 45.42 μ m preoperatively to 509.43 ± 22.49 μ m postoperatively ($p > 0.05$), indicating structural corneal stability. This is illustrated in **Figure 4** and included in **Table 2**.

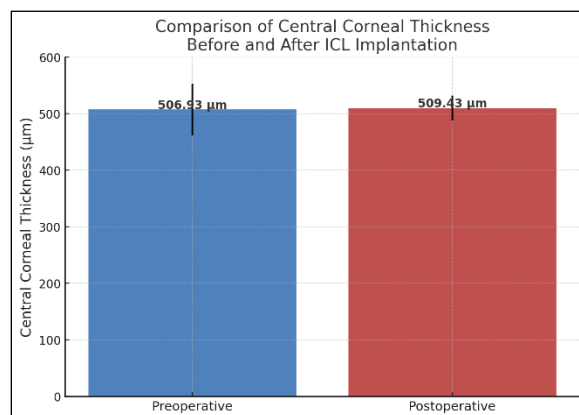


Figure-4: Central corneal thickness before and one month after ICL implantation.

Endothelial Cell Count

The mean endothelial cell density (ECD) decreased from 2800 ± 20.54 cells/ mm^2 to 2705 ± 21.78 cells/ mm^2 postoperatively. Although a slight decrease was observed, the change was not statistically significant ($p > 0.05$), suggesting short-term endothelial safety. The change is presented in **Figure 5** and reflected in **Table 2**.

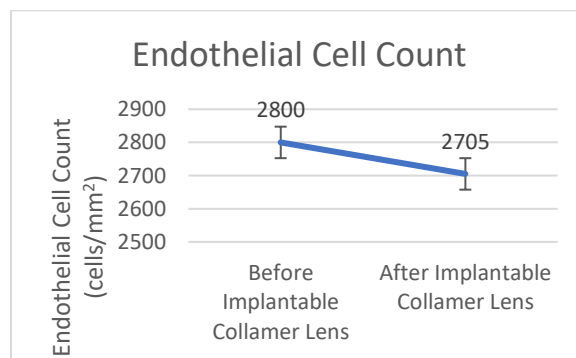


Figure-5: Endothelial cell count before and one month after ICL implantation.

Safety Observations

No intraoperative complications were encountered. During the one-month postoperative period, no cases of cataract formation, pupillary block, pigment dispersion, or secondary glaucoma were reported. All corneal incisions were self-sealing, and all patients experienced uneventful recovery with no signs of inflammation or infection.

DISCUSSION

The present prospective study aimed to evaluate the early outcomes of Implantable Collamer Lens (ICL) implantation in patients with moderate to high myopia, with a specific focus on visual improvement and anterior segment parameter changes. Our findings confirm the clinical effectiveness and short-term safety of the ICL V4 model in this population, aligning with the growing body of evidence supporting its use in refractive correction for patients who are unsuitable for corneal laser surgeries.

Our results showed a significant improvement in refractive status, with the mean spherical equivalent (SE) reduced from -11.49 ± 4.78 diopters (D) preoperatively to -0.87 ± 0.40 D postoperatively ($p < 0.001$). This corresponds with previously published outcomes by Kamiya et al., who reported a similar magnitude of refractive error correction in patients with high myopia over a four-year follow-up period ¹. In a United States FDA trial, Packer et al. also reported comparable refractive stability and predictability, emphasizing the reliability of ICLs for correcting high refractive errors ².

The significant improvement in uncorrected distance visual acuity (UDVA) from 0.11 to 0.87 (decimal Snellen) and in corrected distance visual acuity (CDVA) from 0.85 to 1.0 further supports the efficacy of the procedure. These findings are consistent with those of Yan et al., who observed that over 90% of eyes achieved postoperative UDVA of 20/25 or better, and more than 60% reached 20/20 or better at two years post-ICL implantation ³. The enhancement in CDVA suggests that ICL implantation not only corrects refractive error but also improves the overall quality of vision, possibly due to reduced higher-order aberrations and elimination of spectacle lens-induced optical distortions ⁴.

A major anatomical change observed in this study was the statistically significant reduction in anterior chamber depth (ACD) from 3.32 ± 0.24 mm to 2.59 ± 0.28 mm ($p < 0.0001$) postoperatively. This is in agreement with previous findings by Fernández-Vigo et al. and Ghada et al., who documented consistent reductions in ACD following ICL placement due to

the forward displacement of the iris-lens diaphragm ^{5,6}. While the anatomical narrowing raises concerns regarding the risk of angle-closure glaucoma, our study did not observe any acute postoperative complications such as synechiae or IOP spikes within the first month. This suggests that with proper patient selection and adequate ACD (>3.0 mm), ICL implantation can be safely performed without inducing angle crowding.

The intraocular pressure (IOP) remained stable postoperatively, with a mean change from 17.55 ± 2.04 mmHg to 18.07 ± 2.48 mmHg ($p = 0.20$), indicating no statistically or clinically significant elevation. The central hole design in the V4c model of ICL facilitates aqueous humor circulation, potentially preventing postoperative pupillary block and subsequent IOP elevation ⁷. Several large-scale studies, including those by Lin et al. and Niu et al., have reported similar IOP stability with the central port technology over extended follow-up durations ^{8,9}. However, elevated IOP has been reported in isolated cases, especially when viscoelastic is not completely removed intraoperatively or in eyes with narrow angles ¹⁰. Therefore, meticulous surgical technique and postoperative IOP monitoring remain essential.

The mean central corneal thickness (CCT) showed a slight increase from 506.93 ± 45.42 μ m to 509.43 ± 22.49 μ m, though the difference was not statistically significant. This transient increase may reflect postoperative corneal hydration or subclinical inflammation, which generally resolves within a few weeks. More importantly, the corneal structure remained stable, reaffirming that ICL surgery, unlike LASIK or PRK, does not compromise corneal biomechanics ¹¹.

Endothelial cell count (ECC) showed a mild decrease from 2800 ± 20.54 cells/mm² preoperatively to 2705 ± 21.78 cells/mm² postoperatively, which was not statistically significant ($p > 0.05$). These results align with findings by Igarashi et al. and Fernández et al., who reported minimal endothelial cell loss within the first few months after ICL surgery ^{12,13,14}. However, long-term studies have suggested that endothelial attrition may continue slowly over time, potentially due to chronic proximity of the lens to the corneal

endothelium, vault fluctuations, or anterior chamber inflammation^{15,16}. While our short-term findings indicate satisfactory endothelial safety, regular long-term follow-up is essential, particularly in younger patients who may retain the ICL for decades.

The absence of intraoperative complications and the uneventful postoperative recovery observed in all cases reinforces the procedural safety of ICL implantation when performed under appropriate conditions. Proper sizing of the lens, determined by accurate measurement of the white-to-white (WTW) diameter and ACD, is critical to avoid over- or under-vaulting, which may result in either pigment dispersion glaucoma or cataract formation respectively^{17,18}.

Our study contributes to existing literature by providing short-term real-world evidence from an Indian tertiary care setting, highlighting the safety and efficacy of ICLs in a younger adult population. However, the study has several limitations. The follow-up duration was limited to one month, restricting our ability to assess long-term stability and complications such as cataractogenesis or endothelial decompensation. The relatively small sample size and absence of a control group also limit generalizability and comparative interpretation.

Future studies with extended follow-up, larger sample sizes, and randomized control design are warranted to confirm long-term safety and compare ICL implantation outcomes with those of LASIK, SMILE, or other refractive modalities.

CONCLUSIONS

The results of this prospective, interventional study indicate that Implantable Collamer Lens (ICL) implantation offers a safe and effective surgical option for the correction of moderate to high myopia, particularly in patients who are unsuitable for corneal refractive procedures. The procedure led to statistically significant improvements in both uncorrected and best-corrected visual acuity, with high levels of refractive accuracy demonstrated by the

substantial reduction in spherical equivalent values. These outcomes support the growing consensus in ophthalmic literature that ICL implantation provides high-quality visual rehabilitation without inducing significant postoperative complications during the early follow-up period.

Importantly, our findings show that although anterior chamber depth (ACD) decreases significantly following lens implantation, such anatomical changes did not translate into elevated intraocular pressure (IOP) or other anterior segment pathologies during the short-term postoperative period. This suggests that the central port design in the V4c model effectively maintains aqueous outflow and anterior segment homeostasis. Moreover, the absence of a statistically significant reduction in endothelial cell count further reinforces the corneal safety of the procedure within the one-month follow-up window.

Taken together, these observations highlight the procedural precision and functional benefit of ICL implantation in young adult patients with moderate to high myopia. However, these benefits are maximized when preoperative assessments are rigorous, especially with respect to anterior chamber depth, white-to-white distance, and vault prediction. Advances in imaging technologies, such as Scheimpflug-based tomography, play a vital role in ensuring accurate sizing and long-term anatomical compatibility.

Although our short-term data validate the safety and efficacy profile of the procedure, it is essential to contextualize these results within the limitations of our study design.

LIMITATIONS

The main limitation of this study is the short follow-up period, which precludes assessment of long-term outcomes such as cataract formation or progressive endothelial cell loss. The small sample size and lack of a control group also limit generalizability and comparative analysis. Furthermore, posterior segment evaluation and visual quality metrics were not included. Future studies with longer follow-up, larger cohorts, and comparative designs are necessary to

validate these findings and further characterize the long-term safety and performance of ICLs.

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